Kawa Stream Bioassessment

Susan Burr
Environmental Planning Office
Hawaii Department of Health
February 2001

Acknowledgements

The author wishes to thank the following people for their assistance with the project: Ric Guinther (AECOS), Paul Chong (DOH/CWB), Gordon Smith (USFWS), Anne Brasher and the entire NAWQA crew (USGS), Mike Kido (HSRC), Mike Yamamoto (DLNR/DAR), Annette Tagawa (DLNR/DAR) and The Hawaii Stream Bioassessment Working Group for sharing their knowledge of Hawaii streams;

Ric Guinther, Paul Chong, Lisa Ferentinos, Marjorie Burr, and Eric Gilman for assisting with the field work; and

Ric Guinther and June Harrigan (DOH/EPO) for critical review of the report.

Biological Assessment of Hawaiian Streams

Why Assess Streams

The goal of the 1972 Federal Clean Water Act (CWA) is to achieve "fishable and swimmable" waters for all Americans by restoring and maintaining the chemical, physical, and biological integrity of the Nation's surface waters (33 U.S.C. §1251). The Hawaii State Water Code (Hawaii Revised Statutes (HRS), Chapter 174C-2) states that the waters of the State are held for the benefit of citizens who have a right to have the waters protected for their use. The Hawaii State Department of Health has promulgated regulations (Hawaii Administrative Rules (HAR) Chapter 11-54, Water Quality Standards) that designate uses, set water quality criteria, and establish an antidegradation requirement for all State waters in an effort to meet these national and state goals.

Biennially, the Hawaii Department of Health (HIDOH) compiles a list, the §303(d) List of Water Quality-Limited Segments (List), of surface waters that do not comply with the State water quality standards and then determines the Total Maximum Daily Load (TMDL) of pollutants for the waterbodies that are on this List. Kawa Stream is on Hawaii's 1998 List (HIDOH, 1998) and as a result, the Department of Health is examining the chemical, physical, and biological integrity of the stream in order to calculate TMDLs for Kawa Stream. This bioassessment will be used in coordination with chemical and physical measurements to determine the maximum pollutant load of nutrients and sediments that Kawa Stream can accept and still meet water quality standards (the Total Maximum Daily Load – TMDL).

Hawaii Stream Bioassessment Protocol

The US Environmental Protection Agency (EPA) promotes the use of rapid bioassessment protocols as screening tools to determine if streams support designated aquatic life uses, to characterize the location and severity of use impairment, and to help identify causes of use impairment. The rapid bioassessment protocols compare habitat characteristics and biological metrics with reference conditions (Plafkin et al., 1989).

Most Hawaiian streams are short and steep and have low but flashy flows. Uniquely adapted native animals have evolved in these conditions – some even have the ability to climb waterfalls. These species depend upon heavy rains for reproductive success, and all exhibit an amphidromous lifecycle (lay eggs in freshwater, larvae are carried downstream and drift in oceanic plankton, and juveniles return to streams) (Kinzie, 1990). Native aquatic macrofaunal species are used as biological indicators of stream quality in Hawaii as they are known to be sensitive to environmental degradation, taxonomically unique, readily identifiable, specifically adapted to Hawaiian stream environments, and found on all islands (Kido et al., 1999). Various habitat characteristics are also evaluated to assess the conditions of the environment in terms of the support it provides for the native species.

When assessed together, the habitat characteristics and biological metrics indicate the degree of impairment of a stream and, when evaluated together with various physical and chemical parameters, can be used to determine the TMDL for the stream. Once the TMDL has been estimated, implementation measures will be developed to restore the chemical, physical, and biological integrity of the stream, in line with Clean Water Act goals.

The development of metric scores is done on an ecoregional scale (all main Hawaiian islands), using a data set that includes sites that range in condition from least-impaired to highly degraded. State reference conditions are the set of highest index scores computed in the State, as determined from a representative sample of least impaired streams. Oahu reference conditions are the set of highest index scores for Oahu streams (Smith, 1998). The key to

interpreting the scores assigned to evaluated sites is to compare them to reference conditions (Table 1).

Table 1. ***Guideline values for interpreting attainment of aquatic life uses in Hawaiian streams.***

Habitat	Biological
(% of reference)	(% of reference)
<50% = nonsupporting	<30% = impaired
50-75% = partially supporting	30-70% = moderately impaired
75% = supporting	70% = unimpaired

Kawa Stream

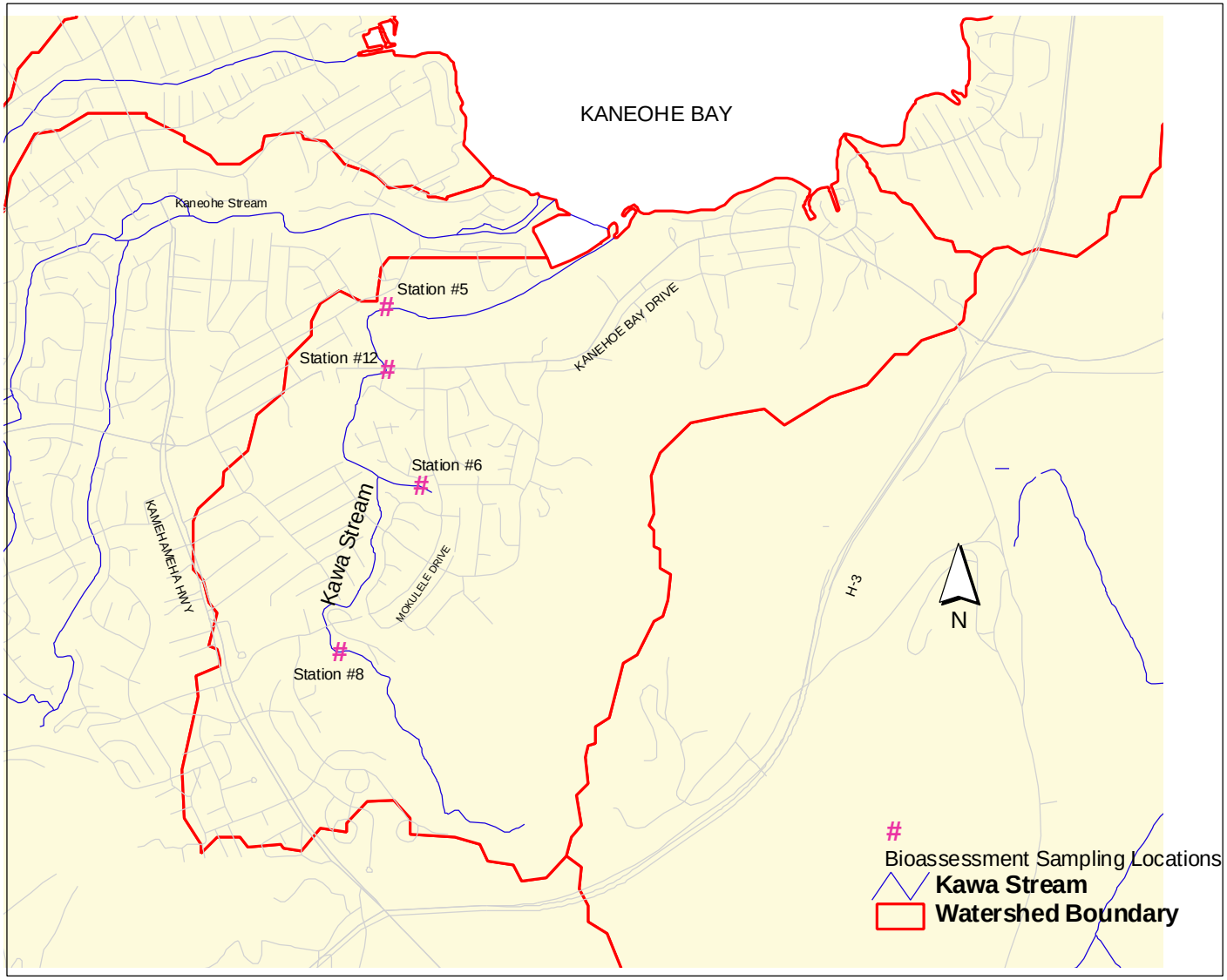
Kawa Stream is the second stream in Hawaii for which the Department of Health has conducted a bioassessment as part of a TMDL assessment. HIDOH conducted the first bioassessment on Waimanalo Stream, also a windward Oahu stream, in 1997 (Smith, 1998). Both assessments follow the Hawaii Stream Bioassessment Protocol (HSBP), with the use of electrofishing techniques instead of the Underwater Visual Census, primarily because the water is too shallow in these streams to snorkel. This Kawa Stream bioassessment follows Version 2.0 of the HSBP (Kido et al., 1999).

The Kawa Stream watershed encompasses approximately 3.3 square kilometers, about half of which is either residential or commercial property, one fourth golf course and cemetery, and one fourth undeveloped hillside land. Kawa Stream originates from a ridge that projects from the Koolau mountains at an elevation of 120 meters in the National Veteran's Cemetery. The stream flows for four kilometers through a small forested section; through the Pikoiloa residential area, where the stream banks are almost completely hardened; through the Bay View Golf Course and past the site of the Kaneohe Wastewater Treatment Plant, where the stream has been channelized through former wetlands; and finally into Kaneohe Bay next to the Waikalua-Loko, an ancient Hawaiian fish pond that is currently being restored (Figure 1). The final 700 meters of the lower section of the stream is tidally influenced.

Kawa Stream flows through an urbanized watershed. Most of the riparian zone adjacent to Kawa Stream has been developed into residential lots. Street storm drains that collect runoff into underground culverts that discharge into the stream handle most of the drainage within Kawa watershed. By 1978, 2.6 km of the stream had been channelized (Flibert and Englund, 1996) and almost the entire length (3.4-km) had been realigned in the name of "flood protection." Two hundred meters of the stream were completely eliminated and the entire lower stream was channelized in 1958 (Brewer/Brandman Assoc., 1989). Several small springs and numerous seeps maintain Kawa's base flow, which is very low, 0.3-0.5 $feet^3/s$ (cfs), even by Oahu standards.

Guinther and Bourke provide a detailed description of the physical characteristics of Kawa Stream on the Koolau.net web page (http://www.pixi.com/~isd/KawaStr.html). The following characterizations of the stream are taken from this web site and site visits during the 2000 dry season.

Figure 1. ***Map of Kawa Watershed***



Upper Reaches

Numerous small branches of Kawa Stream, some of which originate as springs, arise in or near the Hawaiian Memorial Cemetery and National Veteran's Cemetery. The headwaters of the central branch have been buried beneath the cemetery lawn. Grated drains collect sheet flow from the lawns and transfer the water to pipe culverts where it joins the stream in an open concrete box culvert that leads to a pool held back by channel-clogging California grass (*Brachiaria mutica*). The upper east branch drains a forested area east of the cemetery (Figure 2) and the upper west branch arises in a swale behind the cemetery base yard.

Figure 2. Upper East Branch.

Upper Middle Reach

An intermittent waterfall and permanent seeps mark the beginning of the central branch of the Upper Middle Reach. The central branch flows through a steep-sided gulch with juvenile cinnamon trees (*Cinnamomum* sp.) on one side and houses and yards on the other side. The upper west branch arises behind the crematorium and flows over a basalt boulder bed through a forest of cinnamon and mango (*Mangifera indica*) trees. The upper west branch joins the central branch in a concrete open culvert just after it flows through a shallow pool behind the Parkway Community Center that is semi-maintained as a loi`i. The stream then flows over a bedrock bottom with steep soil banks (Figure 3). The middle east branch is a small stream with a bedrock bottom and rock walls that flows through the Pikoiloa housing tract to the vicinity of Pohoi nani.

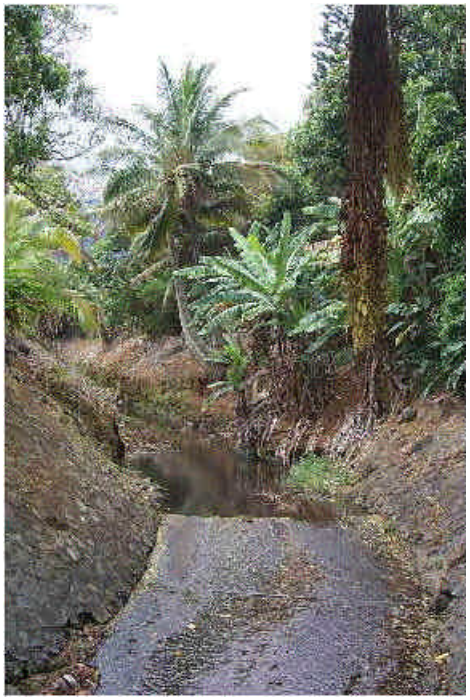


Figure 3. Central Branch of the Upper Middle Reach.

Lower Middle Reach

Land use along the Lower Middle Reach is primarily residential. The reach is composed mostly of long shallow pools separated by riffle zones or artificial drops. Substantial bed erosion is occurring in the Lower Middle Reach; the left banks are steep and bare with weedy terraces and the right banks are mostly lined with concrete as they pass next to a row of houses (Figure 4). The bottom of the Lower Middle

Reach passes through a gulch covered with hau (*Hibiscus tileaceous*) just downstream of Kaneohe Bay Drive.

Figure 4. Lower Middle Reach.

Lower Reach and Estuary
The Lower Reach begins in a large pool with a soft sediment bottom below a basalt outcrop then flows through a channel choked with elephant grass (*Pennisetum purpureum*). Through the golf course and the wastewater treatment plant property, the stream is confined to an artificial unlined channel (Figure 5). The stream flows next to a fish pond, the old Waikalua-Loko, where it is lined with red mangrove (*Rhizophora mangle*), and finally enters Kaneohe Bay beside the fish pond.

Figure 5. Lower Reach.

Assessment of Biological Integrity of Kawa Stream

Methods

Personnel from HIDOH and its contractor, AECOS, selected four sites on Kawa Stream to conduct the bioassessment (see Figure 1). Each assessment site roughly corresponds with a HIDOH Clean Water Branch water quality sampling location and is representative of a larger section of the stream with respect to habitat, biological community, and expected response to human degradation. At each site, we evaluated ten characteristics representative of the quality of stream habitat and ten metrics to measure the biotic integrity from the individual, population, and community levels of ecological organization.

The length of each study site is 20 times the mean width of the stream, or 100 meters, whichever is longer. Each site was divided into four equal-length quadrants within which each of the 20 different metrics were evaluated. The average of the quadrant scores at each site gave us the score for the site.

Each quadrant was examined to the degree that it met optimal conditions for:

Habitat	
Habitat availability	Heterogeneous habitat provides access for stream organisms to a variety of habitat types and hydrologic regimes.
Substrate embeddedness	Maximally exposed cobble and boulder substrate is abundant and limited quantities of sediment exist in the stream.
Fine and course particulate organic matter	Most organic matter is degraded, suspended, and transported out of the watershed.
Velocity-depth combinations	Heterogeneous patterns of stream flow velocity and depth provide a mix of hydrologic regimes that create a variety of physical microhabitats.
Channel flow status	The wetted stream width is nearly as large as the bankfull width, thus providing habitat for aquatic organisms.
Channel alteration	No alteration; maintains physical heterogeneity and natural habitat.
Bank stability	Both banks are intact and show no signs of erosion, maintaining natural habitat heterogeneity.
Riparian vegetative zone width	Intact and functional riparian zones have widths at least four times the mean width of the stream to retard landscape erosion and act as buffers against pollutants entering the water.
Riparian understory coverage	Intact understory plants prevent soil erosion and movement into the stream and maintain habitat for stream organisms.
Percent native riparian plant coverage	High percent of native plants indicate natural riparian conditions and high riparian quality. However, intact native riparian areas are uncommon in Hawaii and 12.5 percent coverage is the optimal expected coverage today.
Biological	
Number of native amphidromous macrofauna	Native species richness is high, but dependent upon slope gradient.
Percent contribution native taxa	Native aquatic species are numerically dominant (>75 percent) and except for the amphidromous alien prawn, *Macrobrachium lar*, alien species are entirely absent.
Percent native fish	At least 50 percent of the sample population of fish is expected to include *Lentipes concolor* or *Sicyopterus stimpsoni*, native species highly sensitive to environmental degradation.
Sensitive native fish density	High densities of sensitive native fish are found in robust fish populations.
Sensitive native fish size	Fifty percent of the sampled population of sensitive native fish should have a total length of at least 6.0 cm, as an indication of robust biotic integrity in terms of reproductive potential, trophic dynamics, species interactions, and environmental support.
Awaous guamensis size	*Awaous guamensis* is relatively common even in degraded streams. Fifty percent of the sampled fish population should have a total length of at least 8.0 cm, as an indication of robust biotic integrity in terms of reproductive potential, trophic dynamics, species interactions, and environmental support.
Total native fish density	Higher total native fish densities correlate with more natural ecological functioning, higher environmental quality, lower numbers of alien species, and reduced human influence.
Community weighted average	Native species dominate the community and alien species are either absent or in very low proportionate abundance.
Number of alien taxa	Streams either have no alien species present or low numbers of *M. lar*.
Percent tolerant alien fish	Even alien species that are highly tolerant of degraded conditions are in low proportionate abundance.

Site Descriptions

Station #8

Upper Middle Reach. Located behind Parkway Park in an undeveloped forested ravine. Mango trees dominate the upper canopy and the rotting fruit is ubiquitous in and around the stream. Young cinnamon trees dominate the understory, although there is little ground cover. The stream is quite narrow at Station #8 (5.0 m) and the only two habitats present are riffles with exposed boulders and dam pools. We did not find any native fish during our surveys, although we had sighted a native goby at a different time. Guppies*, Poecilia reticulata*, dominate the fish community here, although they are relatively rare throughout the rest of the stream.

Station #6

Lower Middle Reach – side branch. Located below the Mokulele Bridge in a bedrock-lined channel with sides that have been almost entirely hardened. Similar to Station #12, but with more pools than riffles. The riparian zone is virtually non-existent; house lots are adjacent to the right side of the stream bank and an access road runs parallel to the stream on the left side. We found one native goby at this site during our surveys, and introduced fishes dominate the fauna.

Station #12

Lower Middle Reach. Located below Castle High School, runs under Kaneohe Bay Drive, and ends in a hau thicket just above an old gaging station, which is currently being used by HIDOH contractors (Oceanit) to measure streamflow. The majority of the stream bank has been hardened or is denuded and eroding as a result of over-application of herbicide. Station #12 has a fair amount of habitat heterogeneity, with riffles with exposed bedrock dominating over short runs and small pools. A large number of non-native aquatic plants were growing in the stream at the time of the surveys (Figure 6). Introduced fishes dominate the fauna, although we found one native goby during our surveys.

Figure 6. Aquatic Plants at Station #12.

Station #5

Lower Reach and Estuary. Located at the bridge next to the driving range in the Bay View Golf Course in the straightened channel running through the golf course. Some of the channel bottom is hardened, there is no riparian zone, and portions of the banks are eroding. Almost all of the site is a shallow-to-moderate dam pool with a slow (<0.20 m/s) flow regime. Despite the lack of habitat heterogeneity, this station was home to all but two of the native macrofauna individuals we found in Kawa Stream during the study.

Results

Ten habitat characteristics and ten biological metrics were evaluated at each station on Kawa Stream and then a score, expressed relative to the statewide reference condition, was assigned to the station. As an interim goal, the values are also compared to the Oahu reference condition.

Station #8

Habitat:

Score 84.2
Percent of statewide reference.....42%
Percent of Oahu reference.....55%
Degree of attainment of aquatic life use.....Nonsupporting

The three habitat characteristics for which Station #8 scored the lowest relative to other Kawa Stream sites are all inter-related: lack of understory, unstable banks, and high substrate embeddedness. While this is the only sizable section of Kawa Stream that remains relatively undeveloped (leading to good scores for lack of channel alteration and adequate riparian zone width) (Figure 7), human activity has so altered the stream that it no longer provides suitable habitat for native macrofauna. The surrounding landscape is dominated by mango and cinnamon trees, leaving significant amounts exposed earth beneath the trees. The lack of vegetation leads to unstable banks and as a result, the natural stream substrate is buried and the optimal heterogeneous habitat structure is eliminated.

Figure 7. Station #8.

All stations monitored at Kawa Stream scored a *zero* for presence of native vegetation, including Station #8. Only one or two individual specimens of native plants or Polynesian-introductions were found at each site.

Biological metrics:

Score 10
Percent of statewide reference.....20%
Percent of Oahu reference.....39%
Evaluation of aquatic life .....Impaired

While the habitat characteristics of Station #8 are good relative to the rest of Kawa Stream, this station scored the lowest possible score for the index of biological integrity. We did not find any native aquatic macrofaunal species, only alien species – primarily guppies (*Poecilia reticulata*), swordtails (*Xiphophorus hereIlil),* and crayfish (*Procambarus clarki*), although during a reconnaissance trip to the site, we observed one native goby in the stream.

Station #6

Habitat:

Score 51.7
Percent of statewide reference 26%
Percent of Oahu reference.....34%
Degree of attainment of aquatic life use .....Nonsupporting

Station #6 scored the lowest in terms of habitat for the sites monitored in Kawa Stream. This small tributary running through the heart of the residential district has been heavily modified by humans (Figure 8). The channel has been straightened, deepened, and lined with concrete, and as a result, the sediment load has increased

and the velocity-depth combinations that create habitat heterogeneity necessary for native macrofauna are nearly absent. Development of the surrounding residential area has eliminated the riparian zone and the concrete-lined banks or bare slopes and cleared access road have all but eliminated the understory.

All stations monitored at Kawa Stream scored a *zero* for presence of native vegetation, including Station #6. Only one or two individual specimens of native plants or Polynesian-introductions were found at each site.

Biological metrics:
Score 12
Percent of statewide reference 20%
Percent of Oahu reference.....39%
Evaluation of aquatic life.....Impaired

The poor habitat characteristics found at Station #6 are reflected in the low index of biological integrity of this site. We found the most number of fish at Station #6 (n=3265, 2±1 fish/sec), dominated by *Poecilia mexicana* (41±19%) and other alien fish highly tolerant of degraded conditions. We also found one native fish, *Eleotris sandwicensis*, during our sampling efforts.

Station #12

Habitat:
Score 77.6
Percent of statewide reference 39%
Percent of Oahu reference.....51%
Degree of attainment of aquatic life use .....Nonsupporting

Figure 9. Station #12.

Station #12 is similar to the other Lower Middle Reach station, #6, although the channel width is larger, the bedrock bottom provides more habitat heterogeneity (Figure 9), and the site has the expected amount of velocity-depth combinations for its slope. However, the majority of the stream banks are lined with concrete or are bare soil that is sprayed with herbicide on a regular basis. There is virtually no understory, and only the lower section of the site has a vegetated riparian zone

(although it is dominated by hau). The ratio of wetted stream width to the ordinary high water mark is low at Station #6, resulting in a loss of habitat for native macrofauna and probably also elevated temperatures.

All stations monitored at Kawa Stream scored a *zero* for presence of native vegetation, including Station #12. Only one or two individual specimens of native plants or Polynesian-introductions were found at each site.

Biological metrics:
Score.....16
Percent of statewide reference 32%
Percent of Oahu reference.....63%
Evaluation of aquatic life.....Moderately Impaired

The aquatic macrofauna at Station 12 are very similar to that of Station 6, a site also of low biological integrity. We found 2131 fish at Site 12 (1±1 fish/sec), which was also dominated by *Poecilia mexicana* (40±15%) and other alien fish highly tolerant of degraded conditions. We found one native goby, *Awaous guamensis*, which was of breeding size (8.0 cm), slightly increasing the Index of Biotic Integrity score over that computed for Site 6.

Station #5

Habitat:
Score 94.1
Percent of statewide reference 47%
Percent of Oahu reference.....62%
Degree of attainment of aquatic life use .....Nonsupporting

Figure 10. Station #5.

Station #5 has characteristics expected of a modified channel flowing through a golf course (Figure 10). Efforts to straighten and deepen the channel have greatly reduced habitat availability and the riparian zone has been virtually eliminated for most of the site. All stations monitored at Kawa Stream scored a *zero* for presence of native vegetation, including Station #5. Only one or two individual specimens of native plants or Polynesian introductions were found at each site.

Although some sections of the bank were eroding, overall, the banks were fairly stable and vegetated with an understory dominated by introduced vines and grasses.

Biological metrics:
Score 16
Percent of statewide reference 32%
Percent of Oahu reference.....63%
Evaluation of aquatic life.....Moderately Impaired

Station 5 provided the greatest surprise for Kawa Stream in terms of native fish. Although we found few fish here (n=377, 0.6±0.5 fish/sec), a sizable portion of the

population was native aquatic macrofauna (9%) – still well below what is considered optimal for a Hawaiian stream not affected by humans (≥75%). The non-climbing eleotrid, *Eleotris sandwicensis*, was the dominant native species (74%), but we also found *Stenogobius hawaiiensis*, commonly found near the stream mouth (Baker and Foster, 1992); the prawn, *Macrobrachium grandimanus*; and *Awaous guamensis*, the native goby considered the most tolerant of environmental degradation.

Despite the presence of a large number of native fish at Station 5 as compared to the other stations on Kawa Stream, the guideline values in Table 1 for evaluation of aquatic life still classify the aquatic community at Station #5 as *Moderately Impaired*.

Discussion

The Hawaii Stream Bioassessment Protocol is a standardized method used by the Hawaii Department of Health to assess stream habitat and biotic quality in the State of Hawaii. The scores can be used to prioritize streams for restoration, and identify both sources of degradation and affected ecological components. Kawa Stream was prioritized for water quality restoration in 1998 when it was placed on the State of Hawaii 303(d) List of Water Quality Limited Waters because it did not meet the narrative criterion expressed in HAR Section11-54-04(a)(5), which prohibits "substances or conditions or combinations thereof in concentrations which produce undesirable aquatic life." The scores from this bioassessment will help quantify the problem and will be valuable in preparing the Total Maximum Daily Load (TMDL) and setting water quality restoration goals for the stream.

The overall habitat quality of Kawa Stream is *Non-supporting* for biotic integrity, causing the biotic integrity of Kawa Stream to be *Moderately impaired to Impaired* (Figure 11). The habitat quality of Kawa Stream ranges from 26 percent at Station #6 to 47 percent at Station #5, with respect to the State reference condition (34 to 62 percent of Oahu reference condition). The biotic integrity of Kawa Stream is 20 percent at Stations #8 and #6 and 32 percent at Stations #12 and #5 (39 and 63 percent of Oahu reference condition).

The different sections of Kawa Stream all share some characteristics of poor habitat quality such as a low percentage of native plants in the riparian zone, a lack of understory, a high sediment load, and embedded stream bottom. The channels have not been hardened at Stations #8 and #5 and the surrounding areas are less urbanized, resulting in better habitat scores, although the altered riparian zones (mango and cinnamon trees at Station #8 and golf course at Station #5) contribute to the eroding banks, high sediment load, and decrease in habitat availability. Stations #12 and #6 are examples of how streams have typically been altered in urban environments in Hawaii. The low habitat quality scores and resulting low biotic integrity scores demonstrate why past attempts to isolate the stream from the surrounding environment by hardening and straightening the channel have typically led to water quality problems and low bioassessment scores. In addition, the poor stream quality in the middle reaches causes problems in both the headwaters and mouth of the stream. No native amphidromous macrofauna were found at Station #8, despite the fact that habitat is available, likely because the animals are unable to traverse the poor habitat and degraded water quality found in the middle reaches. The habitat availability has been reduced at Station #5, partly because of the introduction of sediments from the watershed, which have settled out in the lower reaches of the stream. The vast majority of native amphidromous macrofauna were found at Station #5, never making it to the highly altered reaches that comprise the majority of Kawa Stream.

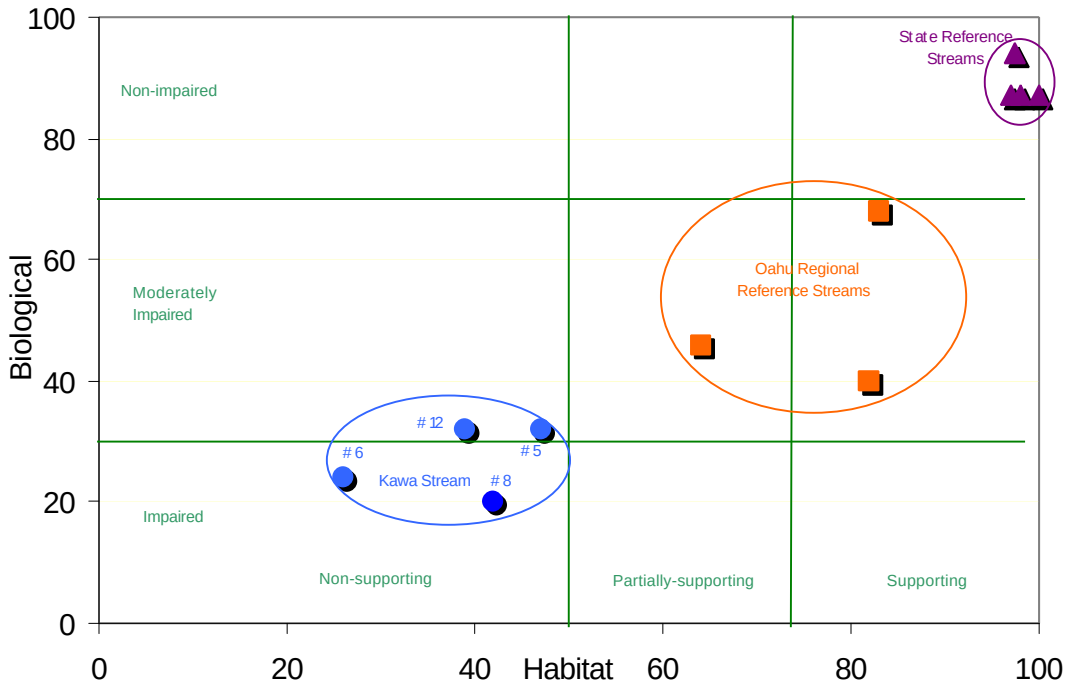


Figure 11. ***Comparison of stream biotic integrity and supporting habitat quality of State and Oahu reference conditions to Kawa Stream.***

The Hawaii Stream Bioassessment Protocol is based upon the premise that habitat quality, biotic integrity, and water quality are inter-related. If the quality of the habitat in Kawa Stream is improved, water quality improvement and reappearance of a native stream ecosystem should follow. Enhancement of the riparian zones to provide "pretreatment" of the runoff from the watershed before it enters the stream and stabilization of stream banks should result in a reduction of sediments entering the stream, along with nutrients and other pollutants that accompany the sediments. Eutrophication supports the herbivorous poecillids that dominate Kawa Stream, including mollies and guppies. A reduction in the trend toward eutrophication may reduce the large biomass of introduced fish species, and a reduction in the sediment load of the stream may make more habitat available to native amphidromous macrofauna.

Setting Environmental Management Goals Using Biological and Habitat Indicators

Water Quality Standards – Designated Uses, Narrative, and Numerical Criteria

Kawa Stream was placed on the 1998 CWA§303(d) List of Impaired Waterbodies because it was found not to meet the narrative criterion expressed in HAR §11-54-04(a)(5), which prohibits "substances or conditions or combinations thereof in concentrations which produce undesirable aquatic life." Before 1999, no one regularly monitored chemical and physical parameters of Kawa Stream to determine compliance with the numeric standards, but a violation of the narrative standards likely means that the numeric standards were also violated; such as the geometric mean of total nitrogen not greater than 180 ug/L and the geometric mean for total phosphorus not greater than 30 ug/L (HAR §11-54-05.2(b)(1) – dry season values). These standards are set for all Hawaiian perennial streams in an effort to limit nutrient loading, which often leads to eutrophication.

A eutrophic stream is not likely to be capable of supporting the designated uses listed in the water quality standards. As set forth in HAR §11-54-03(b)(2), the uses to be protected in Kawa Stream, a Class 2 water, encompass "all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters." A eutrophic stream does not provide supporting habitat for native fish and is not conducive to recreation (Figure 12).

Figure 12. Eutrophic section of Kawa Stream.

As a result of the 303(d) listing, the Department of Health began collecting chemical, physical, and biological data to evaluate the condition of Kawa Stream and to calculate the Total Maximum Daily Load (TMDL). This bioassessment will be used to determine the pollutant load Kawa Stream can accept and still meet the water quality standards (the Total Maximum Daily Load – TMDL).

The following goal defined for Kawa Stream is:

> *Aquatic life uses shall be supported in Kawa Stream; the habitat characteristics shall be improved at least into the range of values indicating* partially supporting *habitat, and the biological community shall be brought at least into the range corresponding to* moderately impaired *as measured by the HSBI.*

This goal is consistent with the goal set for Waimanalo Stream (Smith, 1998). The approach will require the habitat scores to improve from the range of 51.7-94.1 (26%-47% of reference) to the range of 100-150 (50%-75% of reference) and the biotic integrity scores of stations #8 and #6 to improve from the range of 10-12 (20% of reference) to 15-35 (30%-70% of reference) (stations #5 and #12 just fit into the moderately impaired range at 32) [Table 2]. If Kawa Stream is able to reach the partially supporting range for habitat characteristics and moderately impaired range for biotic integrity, it will more closely match the scores achieved by the Oahu reference streams, although it will remain considerably below the Hawaii reference streams. If the target score is met, then Kawa Stream should be capable of supporting the designated uses set forth in HAR §11-54-03(b)(2), even though it is an urban waterbody.

Table 2. Management goals for Kawa Stream.

Attribute	*Current score range*	*Goal score range*
Habitat characteristics	*51.7-94.1*	*100-150*
Biological metrics	*10-16*	*15-35*

Restoration emphasis

The chemical, physical, and biological characteristics of Kawa Stream are inter-connected. The loss of biotic integrity will be the most difficult characteristic to restore directly; however, improving stream habitat and chemical and physical parameters might be enough to restore the biotic integrity of Kawa Stream. Due to the amphidromous nature of the native aquatic macrofauna, the widespread presence of reproductively viable populations throughout the main Hawaiian islands, and the lack of migration barriers on Kawa Stream, the biotic integrity of the stream should improve once the habitat characteristics and chemical and physical water quality parameters reach the score range defined in the Kawa Stream goal and the water quality standards are met.

Because Kawa Stream has been so altered through channelizing and straightening, and much of the riparian zone is developed as a residential area, low-cost, haphazard, and uncoordinated habitat restoration efforts will probably not achieve significant results. The system must be examined as a whole and restoration efforts that are most likely to have a positive downstream benefit should be implemented first. For example, bank stability scored the lowest at Station #8, in the Upper Middle Reach of Kawa Stream. If the bank were stabilized in this section (though not by hardening as this causes negative downstream effects), the sediment load in Kawa Stream would be reduced and lower stations would achieve better scores in the embeddedness and sediment load categories, two of the lowest habitat scores for Kawa Stream as a whole.

We recommend that revegetation efforts take place at every section of stream that is not hardened. The City and County of Honolulu maintenance crews who denude the stream banks near Castle High School with over-application of herbicides should be asked to evaluate their maintenance goals and attempt to find alternative methods to achieve their intended goal (Figure 13). The student population of Castle High School is likely willing to assist in restoration efforts next to their school. The section of Kawa Stream running through the golf course should meet the management goals. The riparian zone should be expanded to meet the minimum requirements to support good water quality. The riparian zone should be planted with native vegetation and an adequate understory should be established. The golf course should also adequately stabilize the sections of the bank that are severely eroding.

Figure 13. Denuded Stream Banks near Castle High School.

These restoration efforts, undertaken in conjunction with a reduction in the nutrient load, should be adequate to improve water quality and eventually support a healthy breeding population of native aquatic macrofauna and decrease the percentage of tolerant alien fish. The Department

of Lands and Natural Resources Division of Aquatic Resources should also be asked to step up their enforcement activities to limit the introduction of tolerant alien fish into Kawa Stream.

Restoration of Kawa Stream to enable it to achieve the required water quality standards will require a high level of public and private cooperation and funding. Kawa Stream functions basically as a storm drain that rushes polluted runoff water from the watershed directly into Kaneohe Bay as quickly as possible – precluding the potential for pollution reduction and recycling that could be accomplished by a normally-functioning stream system. Effective restoration will most likely require more alteration of the stream, but in a way that utilizes natural processes such as riparian buffers and groundwater infiltration. If done properly, the two seemingly disparate goals of flood protection and water quality improvement can be accomplished with the same design.

Literature Cited

Baker, J.A. and S.A. Foster. 1992. Estimating Density and Abundance of Endemic Fishes in Hawaiian Streams. Division of Aquatic Resources, Honolulu, HI. 50 pp.

Barbour, M.T., J.B. Stribling, and J. Gerritsen. 1996. Biological Criteria: Technical Guidance for Streams and Small Rivers – Revised Edition. EPA 822-B-96-001. U.S. Environ. Prot. Agency, Washington, DC.

Brewer/Brandman Assoc. 1989. Baseline marine, estuarine and stream surveys, Bayview Golf Course Expansion, South Kaneohe Bay, Oahu, Hawaii. Prep. for Hida, Okamoto & Assoc. 31 pp.; VTN Pacific. 1977. Environmental impact statement for the Kawa Stream flood control project. Prep. for Dept. Public Works, C & C Honolulu.

Filbert, R. and R. Englund. 1996. Assessment of the Freshwater Macrofauna of Kawa Stream, O'ahu. 19 pp.

HIDOH (1998). Hawaii's Water Quality-Limited Waters: The 1997 Assessment and 1998 CWA §303(d) List of Water Quality-Limited Segments. Pp. 34.

Kido, M.H., G.C. Smith, and D.E. Heacock. 1999. The Hawaiian Stream Bioassessment Protocol (HSBP) Version 2.0: A Manual for Biological Monitoring and Assessment of Hawaiian Streams. 44 pp.

Kinzie, R.A. 1990. Species Profiles: Life Histories and Environmental Requirements of Coastal Vertebrates and Invertebrates, Pacific Ocean Region. Part 3. Amphidromous Macrofauna of Hawaiian Island Streams. Biol. Rept. TR EL-89-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Pacific Atlas (Hawaii), Inc. 1989. Final Environmental Impact Statement: Bayview Golf Course Expansion, Kaneohe, Oahu, Hawaii.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA/444/4-89-001. U.S. Environ. Prot. Agency, Washington, DC.

Smith, Gordon (March, 1998). Biological Assessment and Habitat Characterization of Waimanalo Stream: Establishing Environmental Goals and a TMDL for Watershed Management. Pp. 36.

Stream Bioassessment Program. 1998. Biological Assessment and Habitat Characterization of Waimanalo Stream: Establishing Environmental Goals and a TMDL for Watershed Management. Environmental Planning Office, Hawai'I Department of Health. 36 pp.